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Southwest Division
Naval Facilities Engineering Command
Contracts Department
1220 Pacific Highway, Building 127, Room 112
San Diego, California 92132-5187

Contract No. N68711-92-D-4670

COMPREHENSIVE LONG-TERM ENVIRONMENTAL ACTION NAVY

CLEAN II

IN-WELL AIR STRIPPING EVALUATION AT SITE 24 DRAFT TECHNICAL MEMORANDUM MCAS EL TORO, CALIFORNIA

CTO-0142/0147

January 1998

Prepared by:

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BECHTEL NATIONAL INC.

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DATE: January 14, 1998
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January 14, 1998

Contracting Officer
Naval Facilities Engineering Command
Southwest Division
Mr. Richard Selby, Code 57CS1.RS
Building 127, Room 112
1220 Pacific Highway
San Diego, CA. 92132-5190

Subject: In-well Air Stripping Evaluation at Site 24 - Draft Technical Memorandum

Dear Mr. Selby:

Bechtel National, Inc. (BNI) is pleased to present this Draft Technical Memorandum for In-well Air Stripping to the Department of the Navy, Southwest Division Naval Facilities Engineering Command (SWDIV). The Technical Memorandum was prepared in accordance with Contract Task Order 142 under the Comprehensive Long-Term Environmental Action Navy (CLEAN) II Program, contract No. 68711-92-D-4670. This work was performed to evaluate the feasibility of including in-well air stripping in the ongoing groundwater remediation pilot tests being conducted at Marine Corps Air Station El Toro, Site 24. Based on an evaluation of in-well air stripping mechanics, Site 24 hydrogeology, and the results from previous testing at Edwards Air Force Base, the Technical Memorandum concludes that in-well air stripping is not an applicable technology for removing volatile organic compounds from the groundwater at Site 24 and should not be included in the groundwater remediation pilot tests.

BNI appreciates the opportunity to be of service to SWDIV. If you have any questions regarding this Technical Memorandum, please contact myself at 619-687-8780 or Patrick Brooks at 619-687-8851.

Sincerely,

Patrick Brooks for

Dante J. Tedaldi, Ph.D., P.E.
Project Manager

DJT/sp

Attachment: In-well Air Stripping Evaluation at Site 24 - Draft Technical Memorandum

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ACRONYMS/ABBREVIATIONS

AFB	Air Force Base
atm-m^3/mol	atmosphere per cubic meter per mole
bgs	below ground surface
BNI	Bechtel National, Inc.
CLEAN	Comprehensive Long-Term Environmental Action Navy
cm/s	centimeters per second
CTO	Contract Task Order
DON	Department of the Navy
FS	feasibility study
Hg	mercury
MCAS	Marine Corps Air Station
µg/L	micrograms per liter
mg/L	milligrams per liter
mm	millimeters
PNNL	Pacific Northwest National Laboratory
RAO	remedial action objective
RI	remedial investigation
SWDIV	Southwest Division Naval Facilities Engineering Command
TCE	trichloroethene
VOC	volatile organic compound

Section 1
SUMMARY/INTRODUCTION AND BACKGROUND

This technical memorandum examines the feasibility of including in-well air stripping pilot tests at Site 24 by reviewing in-well air stripping feasibility criteria, reviewing the results of a well-documented pilot test performed at Edwards Air Force Base (AFB), and evaluating site-specific characteristics at MCAS El Toro as they relate to in-well air stripping.

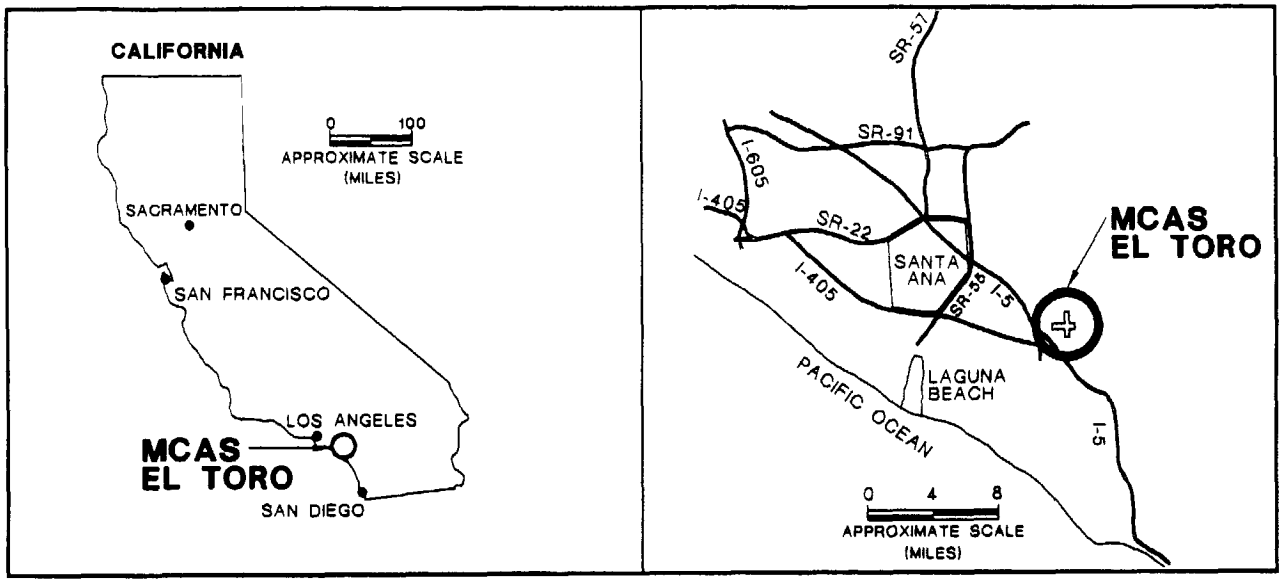
1.1 SUMMARY/INTRODUCTION

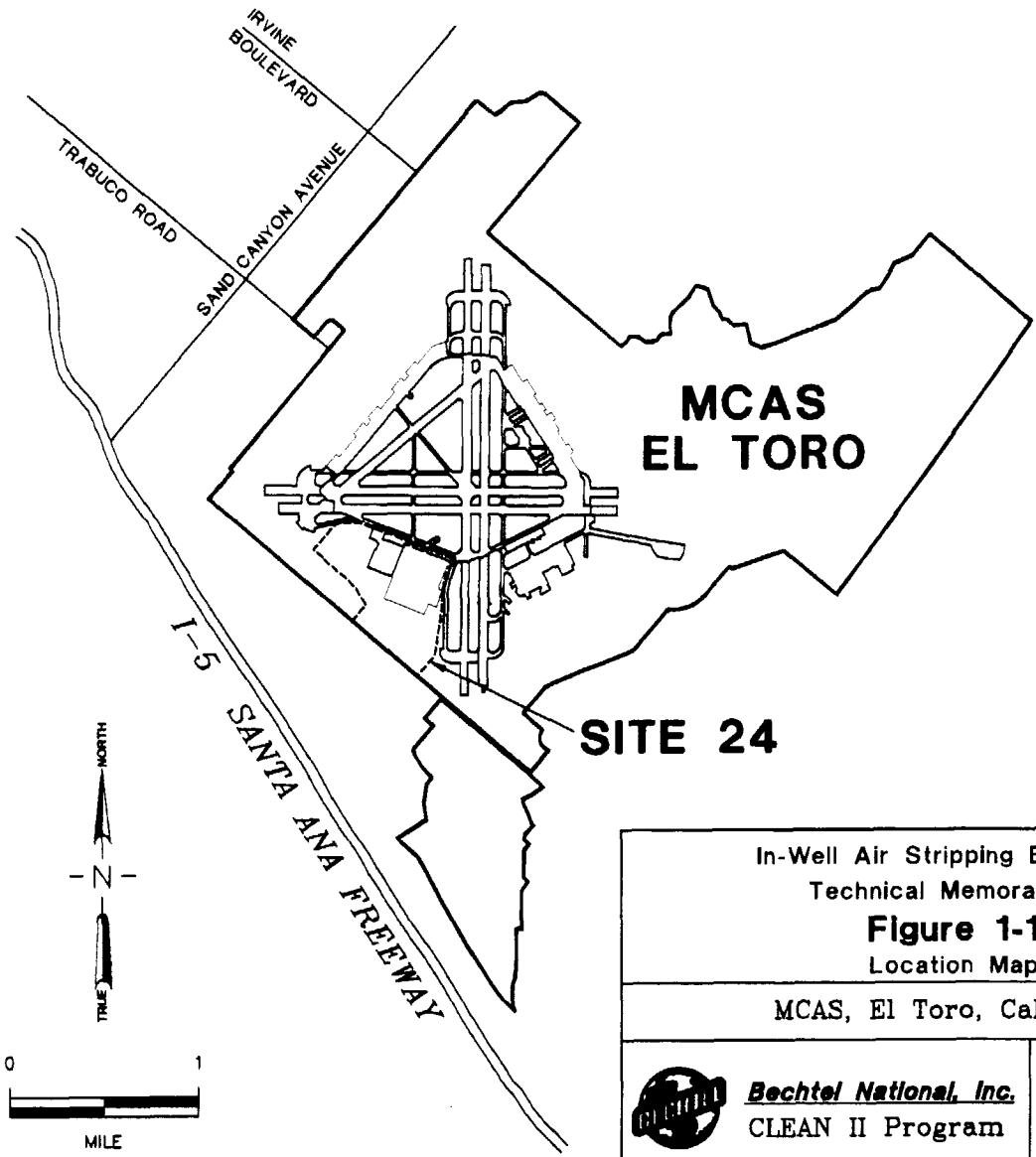
This technical memorandum examines the feasibility of conducting an in-well air stripping pilot test at Site 24, Marine Corps Air Station (MCAS) El Toro (Figure 1-1). The technical memorandum was prepared by Bechtel National, Inc. (BNI), on behalf of the U.S. Department of the Navy (DON), Southwest Division Naval Facilities Engineering Command (SWDIV), in accordance with Contract Task Order (CTO)-0142. This CTO was issued under the Comprehensive Long-Term environmental Action Navy (CLEAN) II Program, contract No. N68711-92-D-4670. Based on the analyses presented in this technical memorandum, in-well air stripping pilot tests are not recommended at Site 24.

1.2 BACKGROUND

In-well air stripping was identified as a potential technology to support vacuum-enhanced groundwater extraction in the draft Phase II Feasibility Study (FS) for Site 24 (BNI 1996a). In-well air stripping is one of several technologies that can be used to treat volatile organic compound (VOC)-contaminated aquifers. Groundwater remediation pilot tests are currently being conducted at MCAS El Toro to evaluate groundwater extraction, vacuum-enhanced groundwater extraction, and groundwater treatment with activated carbon before injection back into the aquifer.

During 1995, air sparging pilot tests were conducted at two wells located at Site 24 (BNI 1996b). These pilot tests were conducted to evaluate the feasibility of using air sparging to remove VOCs from the shallow groundwater unit at Site 24. The results of the air sparging pilot tests indicated that VOC concentrations in groundwater were reduced over the period tested, and that air sparging bubble flux could be measured from one of the test wells (24AS1). However, in one of the test wells (24AS2A), airflow could not be controlled or monitored in the subsurface. In the test at well 24AS2A, injected air passed into the aquifer but could not be monitored at an observation well approximately 10 feet away due to aquifer stratification with low-permeability layers. These results suggest that air injected into the aquifer may have been channeled beneath low-permeability layers, which may prevent sparging bubbles from rising to the water table. This reduces the volume of aquifer that receives treatment, and may prevent sparging bubbles from being captured in the vadose zone.





In-Well Air Stripping Evaluation
Technical Memorandum

Figure 1-1

Location Map

MCAS, El Toro, California

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Date: 12/16/97
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1.3 TECHNOLOGY DESCRIPTION

In-well air stripping is an *in situ* process that strips VOCs from groundwater by injecting air into a specially designed dual-screened well. The basic components of an in-well air stripping system consist of a well casing set in the saturated zone with separate upper and lower screened intervals. The lower screened interval is generally located near the base of contamination, and the upper screened interval spans the distance just below the water table and extends into the vadose zone. An air-injection line placed inside the well casing extends into groundwater, but not necessarily to the depth of the lower screened interval. Figure 1-2 illustrates the generalized design components of an in-well air stripping system, and it shows how the system would work in a homogeneous and heterogeneous aquifer.

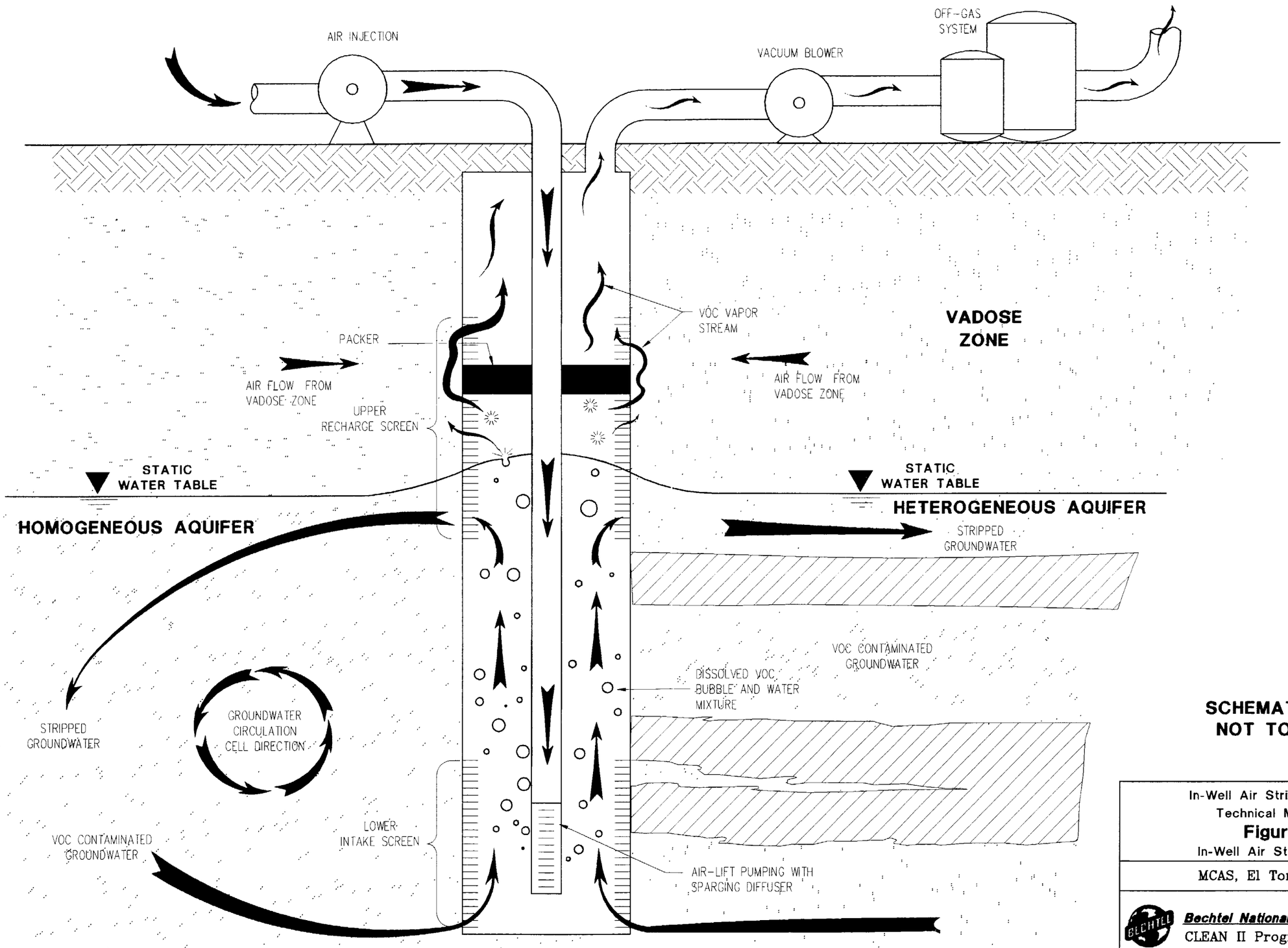
As air is injected into the stripping well, the injected air acts as an air-lift pump mechanism causing contaminated groundwater to enter the well through the lower screened interval and be lifted toward the ground surface. The air-lift mechanism is caused by a differential pressure between the well and aquifer due to the formation of less dense aerated water. A pressure gradient develops between the less dense water inside the well and the denser water outside the well. As a result of this pressure gradient, groundwater is drawn into the well from the surrounding aquifer. Contaminated groundwater is lifted upwards where it comes in contact with the injected air. When VOC-contaminated water comes in contact with the clean air, VOCs are stripped from the groundwater into air bubbles. A vacuum-extraction blower is used to capture air containing VOC vapor. The captured vapor can be treated using an activated-carbon treatment system or other means before discharge to the atmosphere. The VOC-stripped water passes over a deflection plate located at the upper screened interval, and it is forced back into the aquifer as recharge. Water flow from the upper to the lower well screen creates a circulation cell if low-permeability layers within the aquifer do not prevent vertical groundwater movement. In homogeneous aquifers, water may be drawn several times for treatment before moving downgradient.

1.4 IN-WELL AIR STRIPPING OBJECTIVES

To be effective as a remedial technology at Site 24, in-well air stripping must be capable of accomplishing the remedial action objectives (RAOs). The RAOs for Site 24 include (BNI 1997a):

- preventing migration of groundwater above cleanup levels (5 µg/L for TCE) in the shallow groundwater unit beyond the point of compliance; and
- reducing concentration of VOCs in the Site 24 shallow groundwater unit downgradient of the point of compliance to federal or state cleanup levels.

In summary, in-well air stripping must be capable of reducing TCE concentrations in the shallow groundwater unit to 5 µg/L.



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In-Well Air Stripping Evaluation
Technical Memorandum

Figure 1-2

In-Well Air Stripping System

MCAS, El Toro, California

Bechtel National, Inc.
CLEAN II Program

Date: 12/29/97
File No: 142M2373
Job No: 22214-142
Rev No: C

Section 2
IN-WELL AIR STRIPPING FEASIBILITY EVALUATION

This section discusses those conditions which should be met for an in-well air stripping system to be effective. These conditions are compared to conditions and requirements at Site 24. A well-documented in-well air stripping pilot test is also summarized.

2.1 FEASIBILITY CRITERIA

Metcalf and Eddy, Inc., is a license holder for one of the patented processes for in-well air stripping. Based on information provided by Metcalf and Eddy (1997a,b), several criteria should be used in screening sites before implementing in-well air stripping. The feasibility criteria are summarized in Table 2-1.

2.1.1 Contaminant Properties

The contaminants of concern at Site 24 are VOCs. The contaminant reported most often and at the highest concentrations is trichloroethene (TCE) (BNI 1997b). Chemical and physical properties of TCE meet the feasibility criteria for Henry's law constant, volatility, and solubility. Thus, TCE can be readily removed via the air stripping process. However, TCE is not amenable to biodegradation under aerobic conditions that are promoted by in-well air stripping.

Table 2-1
Feasibility Criteria for In-Well Air Stripping

Factor	Parameter	Limits/Desired Range
Contaminant	Henry's law constant	$> 5 \times 10^{-4}$ atm-m^3/mol[a]
	Volatility	> 5 mm[b] Hg[c]
	Solubility	< 20,000 mg/L[d]
	Biodegradability	not required, but enhances cleanup
Geology	Hydraulic conductivity	$> 5 \times 10^{-4}$ to 5×10^{-5}cm/s[e]
	Stratigraphy	Aquifers should not be stratified with low-conductivity layers
	Vadose zone	> 10 feet
	Saturated zone	> 10 feet

Notes:
[a] atm-m^3/mol – atmosphere per cubic meter per mol
[b] mm – millimeters
[c] Hg – mercury
[d] mg/L – milligrams per liter
[e] cm/s – centimeters per second

2.1.2 Aquifer Characteristics

Geologic factors that influence the performance of in-well air stripping include aquifer thickness, hydraulic conductivity, and aquifer heterogeneity. In general, the horizontal aquifer hydraulic conductivity should be greater than 5×10^{-4} to 5×10^{-5} centimeters per second (cm/s). The aquifer should also be free of low-conductivity layers that would hamper the formation of circulation cells. In-well air stripping is most effective in homogeneous aquifers with high hydraulic conductivity.

Aquifer testing at Site 24 conducted during the Phase II Remedial Investigation (RI) showed that the average horizontal hydraulic conductivity ranged from about 5 to 15 feet per day or 1.5 to 5.4×10^{-3} cm/s (BNI 1996b), which is within the range specified. The aquifer also meets the feasibility criteria for thickness. However, the aquifer is extremely stratified with silt and clay layers that exhibit low vertical conductivity, ranging from 3.9×10^{-6} to 3.5×10^{-9} cm/s (BNI 1997b). Figure 2-1 presents cross sections that illustrate the aquifer stratification at Site 24. The results from soil samples analyzed for vertical hydraulic conductivity are also shown.

Figure 1-2 illustrates how a heterogeneous aquifer could prevent the formation of circulation cells by channeling groundwater flow between low-permeability zones. Without an effective circulation cell, some of the contaminated aquifer does not receive treatment.

2.1.3 Control of TCE Removal

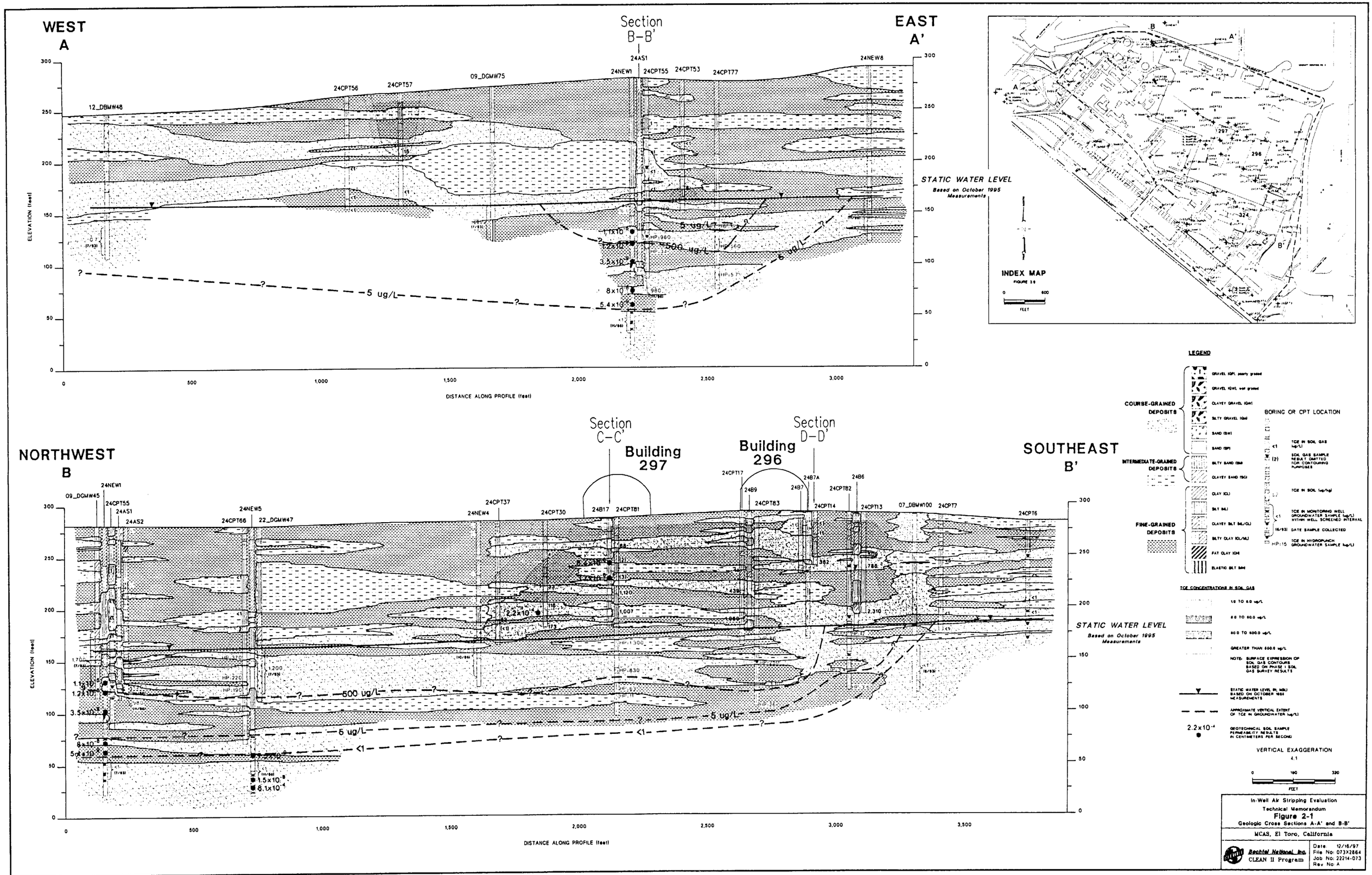
For a treatment system to be effective, one must be able to match the degree of treatment to the removal requirement. In the case of Site 24, the system has to be capable of reducing TCE concentrations in the shallow groundwater unit to 5 µg/L. Both contaminant properties and aquifer characteristics influence the ability of in-well air stripping to achieve this objective.

2.2 PREVIOUS ASSESSMENT AT EDWARDS AIR FORCE BASE

A demonstration of in-well air stripping was conducted at Edwards AFB for approximately 6 months during 1996. The demonstration was conducted by collaborating researchers from Pacific Northwest National Laboratory (PNNL), Stanford University, Earth Technology Corporation, and EG&G Environmental. Groundwater beneath the site is contaminated with dissolved VOCs, primarily TCE.

2.2.1 Site Conditions

Edwards AFB was selected as a demonstration site based on several criteria, including availability of hydrogeologic data, presence of VOC contamination in the aquifer, no known co-contamination in the vadose zone, hydraulic conductivity near the low range specified (10 feet per day), and a low hydraulic gradient. Additional characterization revealed two zones of low hydraulic conductivity (one near the water table at 29 feet



In-Well Air Stripping Evaluation
Technical Memorandum
Figure 2-1
Geologic Cross Sections A-A' and B-B'

MCAS, El Toro, California

Bechtel National, Inc.
CLEAN II Program

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Job No: 22214-073
Rev No: A

below ground surface [bgs] and one at 44 feet bgs). The maximum TCE concentration at the pilot test site was 502 micrograms per liter (μg/L), but the TCE concentrations averaged about 300 μg/L (PNNL 1996). Table 2-2 summarizes the site conditions at Edwards AFB and compares them to conditions at MCAS El Toro.

Table 2-2
Comparison of Site Characteristics

Parameter	Edwards Air Force Base	MCAS* El Toro
Groundwater contaminant	Trichloroethene	Trichloroethene
Depth to water	25 feet	100 feet
Contaminated aquifer thickness	25 feet	40 to 60 feet
Aquifer sediments	Fine sand with interbedded silt	Fine sand with interbedded silt and clay; some gravely sand
Porosity	0.155 to 0.313	0.153 to 0.28
Hydraulic gradient	0.005	0.008
Horizontal hydraulic conductivity	10 feet/day	4.3 to 15.3 feet/day
Anisotropy ratio	10:1	>>100:1
Average linear velocity	0.2 feet/day	0.4 feet/day

Note:
* MCAS – Marine Corps Air Station

2.2.2 Pilot Test Summary

The pilot test at Edwards AFB was conducted almost continuously for 6 months. The air stripping well was operated with an intake screen at the bottom and a discharge screen at the top as shown in Figure 1-2. The pumping rate varied between about 7 to 10 gallons per minute. Approximately 20 groundwater samples were collected from each well in the monitoring network over the duration of the pilot test. The monitoring wells were screened to evaluate groundwater quality in both shallow (water table) zone and a deeper zone.

Groundwater samples collected from shallow groundwater monitoring wells showed the greatest decreases in TCE concentration, while the deeper wells remained fairly constant. Copies of the pilot test site plan and graphs of TCE concentration versus time for the monitoring wells are included as Appendix A.

The concentration profiles suggest that the zone of influence was greatest in the shallow zone, where TCE declined in all the monitoring wells. In the deeper zones, TCE concentrations declined in well M3, located 10 feet from the demonstration well. In the other deep wells, the concentration declines were not as apparent. These data indicate that the rate of circulation in the deeper zone is low. PNNL attributed this to the low-permeability zone present at about 44 feet bgs.

In summary, the pilot test demonstration showed that TCE concentration could be reduced significantly, but the decrease in concentration with respect to distance and depth was asymmetrical due to the heterogeneous nature of the site geology.

Section 3
CONCLUSIONS

Based on the feasibility criteria established by Metcalf and Eddy, comparison of these criteria to Site 24 conditions, and an evaluation of the results of a pilot test conducted at Edwards AFB, the following conclusions have been reached.

- In-well air stripping is a viable technology that can be used to reduce VOC concentrations in some contaminated aquifers.
- In-well air stripping is most applicable in homogeneous aquifers with moderate to high hydraulic conductivity (greater than 5×10^{-5} cm/s) and low values of vertical anisotropy, as these conditions promote the formation of circulation cells.
- Aquifers that exhibit a high degree of heterogeneity have asymmetrical flow fields that result in uneven decline or no decline in VOC concentrations over time.
- The high degree of heterogeneity and vertical anisotropy in the shallow groundwater unit at Site 24 combined with the thickness of the contaminated zone make the effective implementation of in-well air stripping difficult, and implementation therefore would have potential problems. Without the formation of circulation cells, some of the contaminated groundwater will not receive treatment.
- It is questionable whether an in-well air stripping system can be designed and operated to produce treated groundwater throughout the shallow groundwater unit at the prescribed cleanup level for TCE (5 μg/L).
- In-well air stripping pilot tests are not recommended at Site 24.

Section 4
REFERENCES

Bechtel National Inc. 1996a. Draft Phase II Feasibility Study Report, Operable Unit 2A – Site 24, Marine Corps Air Station El Toro. August.

———. 1996b. Air Sparging Pilot Test Report, Operable Unit 2A – Site 24, Marine Corps Air Station El Toro. November.

———. 1997a. Draft Final Phase II Groundwater Feasibility Study, Operable Unit 2A – Site 24, Marine Corps Air Station El Toro. December.

———. 1997b. Draft Final Phase II Remedial Investigation Report, Operable Unit 2A – Site 24, Marine Corps Air Station El Toro. March.

BNI. *See* Bechtel National, Inc.

Metcalf and Eddy. 1997a. No VOCs™ Recirculating In-Well Stripping Qualifications. April.

———. 1997b. No VOCs™ In-Well Stripping Technology. August.

Pacific Northwest National Laboratory. 1996. Performance Assessment of the In-Well Vapor-Stripping System. October.

PNNL. *See* Pacific Northwest National Laboratory.

APPENDIX A

EDWARDS AIR FORCE BAS PILOT TEST SITE PLAN AND GRAPHS OF TCE CONCENTRATION VERSUS TIME

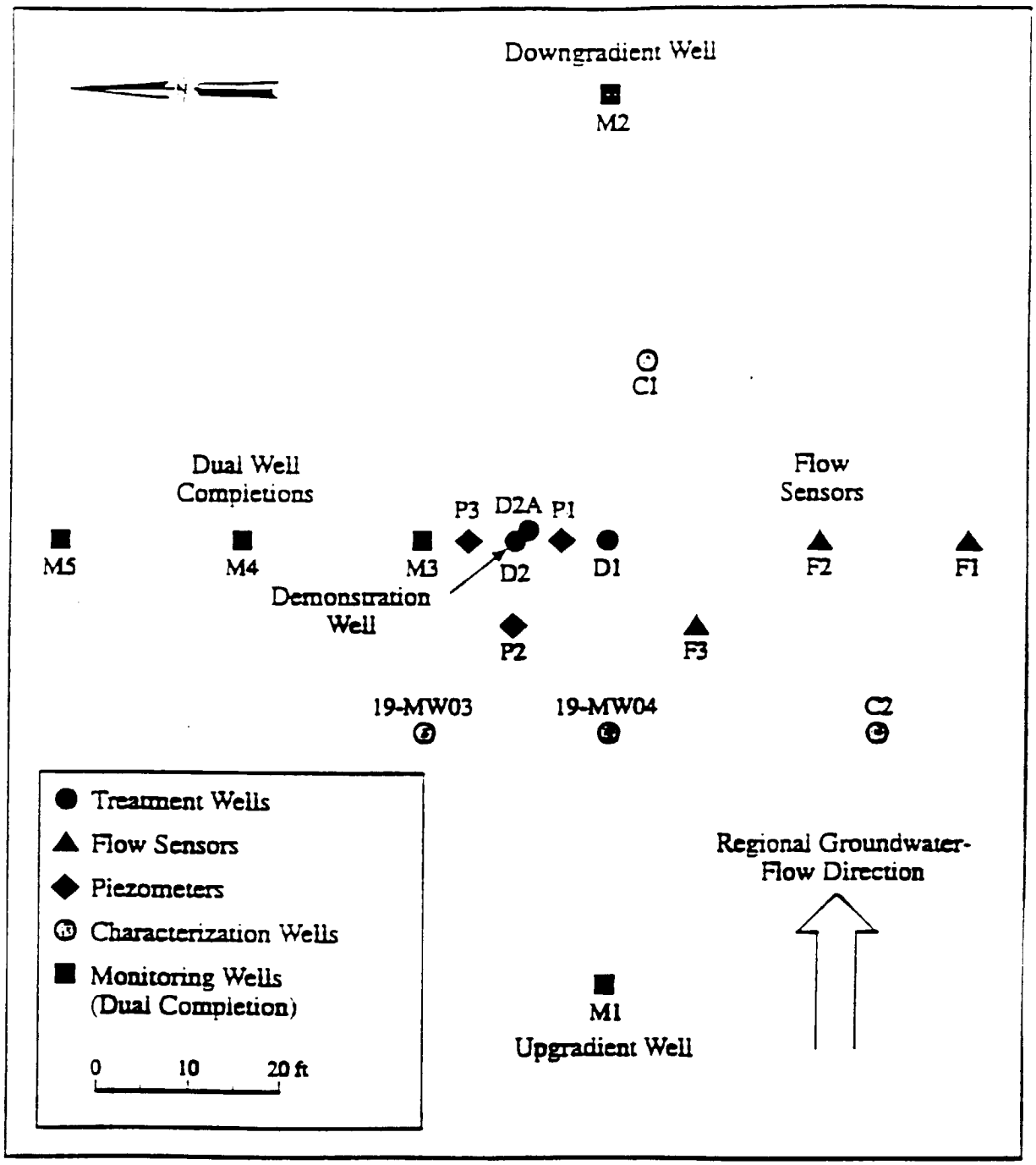

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Figure 6.1. Monitoring Well Network

Reference: Pacific Northwest National Laboratory, Performance Assessment of the In-Well Vapor Stripping System, 1996

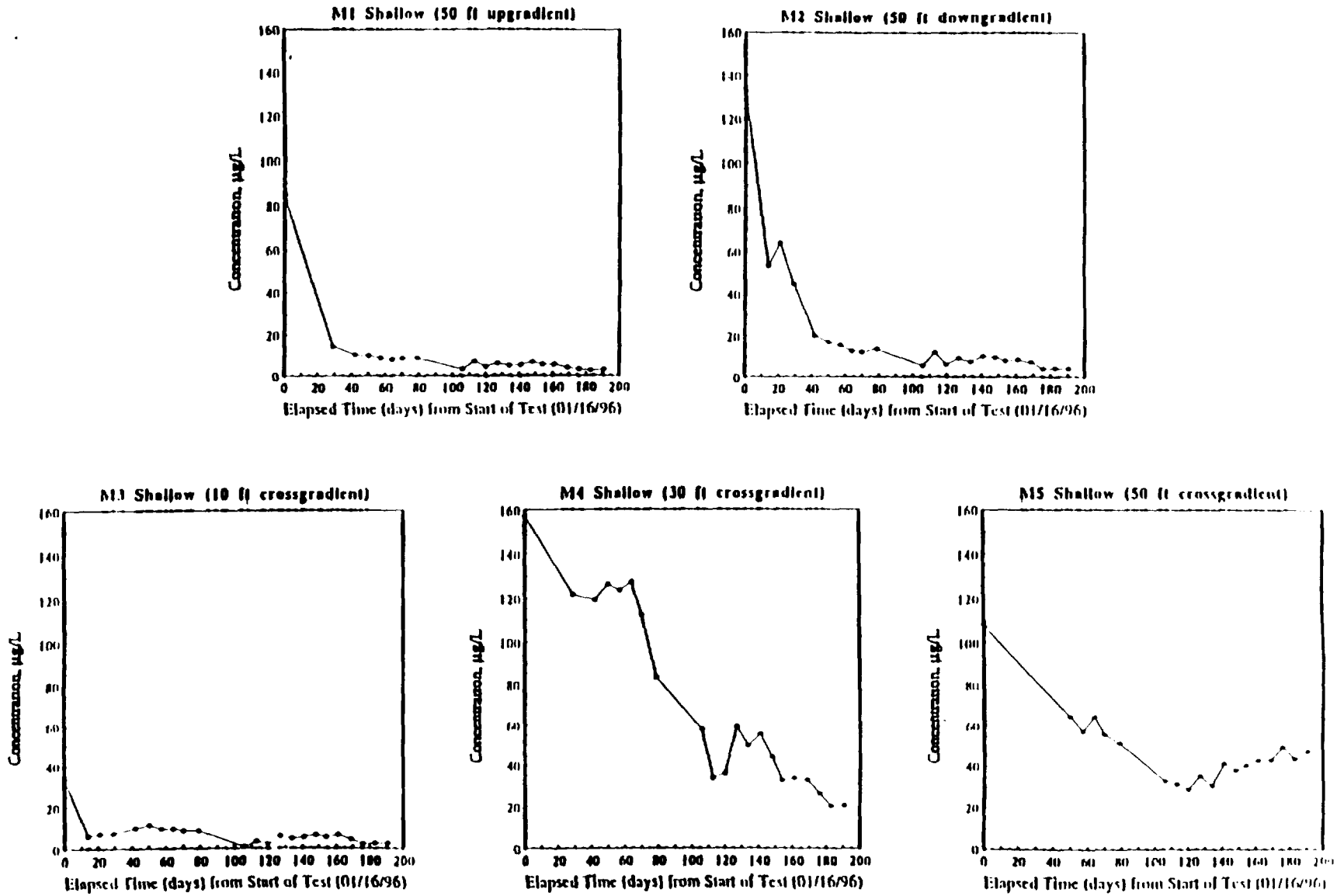

Figure 11.1. Trichloroethylene Concentrations in Shallow Monitoring Wells

Reference: Pacific Northwest National Laboratory, Performance Assessment of the In-Well Vapor Stripping System, 1996

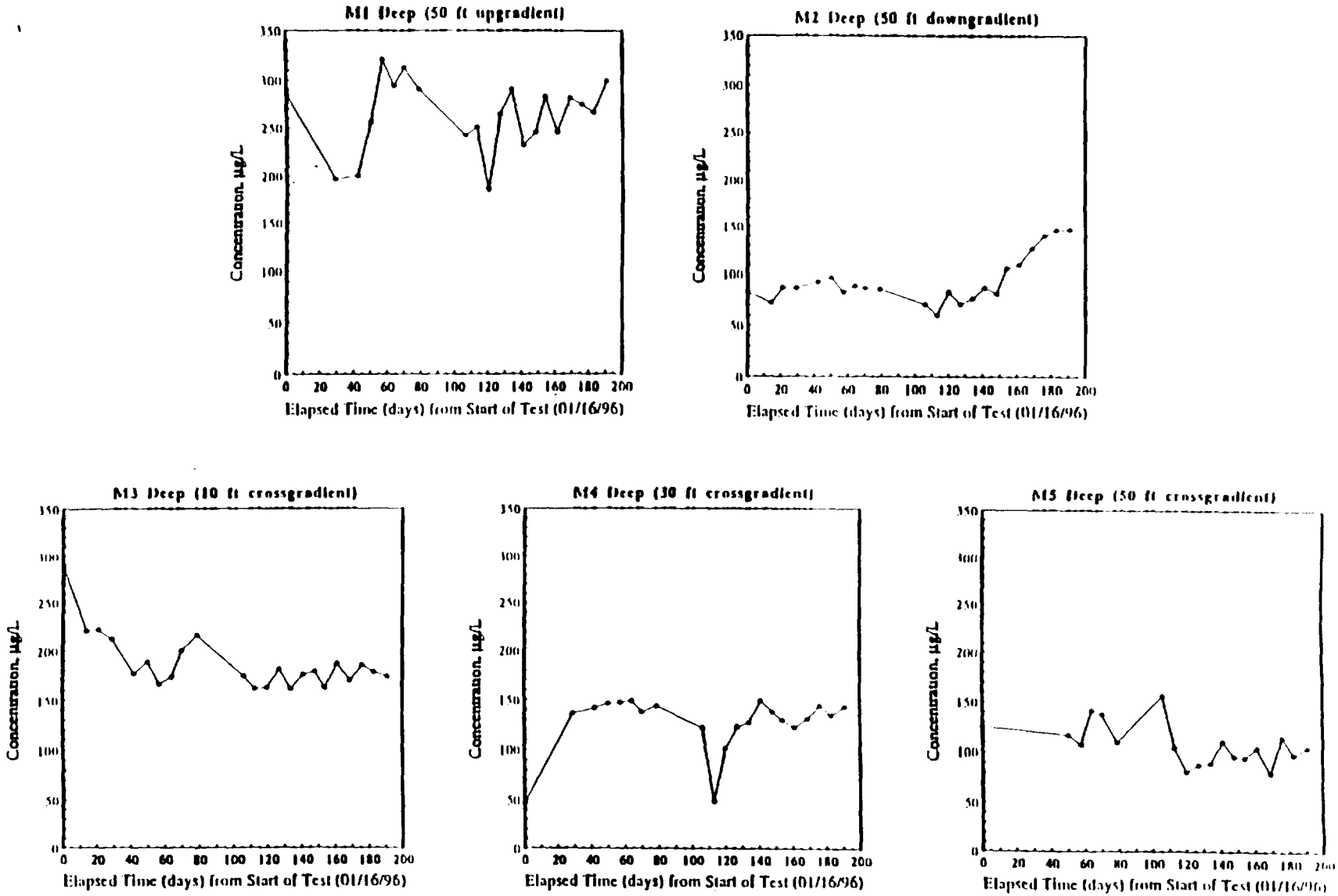

Figure 11.2. Trichloroethylene Concentrations in Deep Monitoring Wells

Reference: Pacific Northwest National Laboratory, Performance Assessment of the In-Well Vapor Stripping System, 1996